Fundamental and Applied Agriculture
Vol. 5(3), pp. 372–382: 2020
doi: 10.5455/faa.125478

Agronomy | Original Article

Impact of weed control practices on weed suppression and crop performance in *boro* rice

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Article Information

Article History
Submitted: 14 Aug 2020
Accepted: 13 Sep 2020
First online: 29 Sep 2020

Academic Editor
AKM Mominul Islam
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Abstract

Weed control is important to prevent yield loss and production costs, and to preserve quality grain. Therefore, a study was conducted during December 2016 to May 2017 to find out appropriate weed management practices in *boro* rice. Two *boro* rice varieties namely, BRRI dhan28 and BRRI dhan29 were included in the study. Twelve different combinations of herbicidal weed managements *viz.*, No weeding, Amchlor 5G or Talon 52WP as pre-emergence, Supermix 18WP or Clean master 18WP as post-emergence, Amchlor 5G followed by Supermix 18WP or Clean master 18WP, Talon 52WP followed by Clean master 18WP or Supermix 18WP, Amchlor 5G + Supermix 18WP + Hand weeding at 35 DAT, Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT, and Two hand weeding were included in this experiment following single factor randomized complete block design with three replications. The maximum weed density (74.0 m^{-2} in BRRI dhan28 and 65.0 m^{-2} in BRRI dhan29) and biomass (38.2 g m^{-2} in BRRI dhan28 and 31.25 g m^{-2} in BRRI dhan29) were found in no weeding treatment and that of the lowest was obtained from Talon 52WP + Clean master 18WP + one hand weeding at 42 DAT. The highest grain yield (5.5 t ha^{-1} in BRRI dhan28 and 6.23 t ha^{-1} in BRRI dhan29), net return (58050 Tk ha^{-1} in BRRI dhan28 and 61229 Tk ha^{-1} in BRRI dhan29) and B:C ratio (1.81 in BRRI dhan28 and 1.86 in BRRI dhan29) were recorded when Talon 52WP + Clean master 18WP + one hand weeding at 42 DAT was applied. The lowest was obtained from the unweeded plots of both varieties. Based on this results Talon 52WP + Clean master 18WP + one hand weeding at 42 DAT was the best weed management practice in terms of efficacy and economics for both *boro* rice varieties.

Keywords: Weed management, herbicide, Importance Value, net return, Benefit Cost Ratio

Cite this article: Monira S, Begum M, Uddin MR. 2020. Impact of weed control practices on weed suppression and crop performance in *boro* rice. Fundamental and Applied Agriculture 5(3): 372–382. doi: 10.5455/faa.125478

1 Introduction

Economic losses in agricultural production due to weed are of utmost importance in modern day input intensive agricultural systems. Globally, the highest potential loss (approximately 34%) produced by weed in comparison to animal pests (18%) and pathogens (16%) (Oerke, 2005). In rice, about 40-60% average yield loss because of weed competition was estimated and it may increase up to 94-96% under season long weedy condition (Chauhan and Johnson, 2011; Ramana et al., 2007; Islam et al., 2017). However, the degree of yield reduction resulting from crop-weed competition varies from country to country. In China, every year about 10 million tons of rice is lost owing to weed infestation (Zhang, 2003). And, in Sri Lanka, the estimated yield reduction in rice due to weeds was around 30-40% (Abeysekera, 2001). On the other side, it was reported that in Bangladesh, weeds decrease the grain yield by 70-80%, 30-40% and 22-36% in *aus*, transplanted *aman* and modern *boro* rice, respectively (BRRI, 2008). The climatic as well as the edaphic condition of these countries are congenial for vigorous growth of many noxious weeds and it provides a severe competition with rice crop. Ashiq and Aslam (2014) reported that weeds compete with crop for different growth promoting resources such as light, air, water, space as well as nutrients and adversely affect the crop growth, grain yield and quality as well. Therefore, weed management is very crucial for increasing the rice yield.

Now a days, herbicidal weed control is gaining popularity in Bangladesh because of its miraculous results such as rapid effect on weed, easier to application and more cost effective compared to commonly used conventional methods of weed control. As stated by Anwar et al. (2012), weed management using herbicide has considered as the smartest and most viable alternative in large-scale farming due to the unavailability and rising wages of labor. It motivates the farmers more on using herbicides to manage the weeds effectively. But from sustainability point of view the single use of chemical method is not feasible. Repeated application of herbicides for a long time is very congenial for producing herbicide resistant weed species and causes shifting of weed flora (Chauhan and Opeña, 2013). So, this problem can be minimized by combining hand weeding with herbicide or combination of different pre-emergence or post-emergence herbicides to enhance their efficacy (Dhakal et al., 2019; Popy et al., 2017). In addition, the maximum weed biomass reduction and maximum yield increase were observed with the successive application of pre-emergence herbicide (pendimethalin) and post-emergence herbicide (bispyribac-sodium bazimsulfuron) (Singh et al., 2016). However, efficiency of an herbicide is mostly determined by their ability to develop the desired effects on the target pests. While, it is expected for herbicides to kill weeds but not expected for them to sustain and retard the subsequent growth and development of crop. Besides, the suitability of an herbicide not only determined by its efficacy but also determined by its cost effectiveness. The application time as well as appropriate management of herbicide should be considered before selecting herbicide. Moreover, integration of herbicides along with other weed control practices is the fundamental requirement of Integrated Weed Management (IWM) strategies. Hence, the study was conducted with a view to evaluate the weed control efficiency as well as the cost-effectiveness of different herbicidal weed management practices in *boro* rice varieties.

2 Materials and Methods

2.1 Experimental site and soil

The study was carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh (24°43′9″N, 90°25′43.8″E) during the period from December 2016 to May 2017. The monthly average maximum and minimum temperature, and relative humidity were 23.5-35.1 °C, 12.3–23.0 °C and 75.3–86.2%, respectively, while monthly total precipitation and sunshine hours were 0-445.3 mm and 132.5-225.4 h, respectively.

2.2 Experimental treatment and design

This experiment included single factor. In this experiment 12 different combinations of herbicidal weed managements *viz*., No weeding (W0), Amchlor 5G as pre-emergence (W1), Talon 52WP as pre-emergence (W2), Supermix 18WP as post-emergence (W3), Clean master 18WP as post-emergence (W4), Amchlor 5G + Supermix 18WP (W5), Amchlor 5G + Supermix 18WP + Hand weeding at 35 days after transplanting (DAT) (W6), Amchlor 5G + Clean master 18WP (W7), Talon 52WP + Clean master 18WP (W8), Talon 52WP + Supermix 18WP (W9), Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT (W10), Two hand weeding at 21 and at 42 DAT (W11) were included as treatments. Two *boro* rice varieties such as, BRRI dhan28 and BRRI dhan29, were selected to observe the effect of abovementioned treatments. The experiment was laid out according to randomized complete block design with three replications. An overview about the herbicides used in this experiment is provided in Table 1.

2.3 Plant materials

BRRI dhan28 and BRRI dhan29, modern high yielding varieties of rice, were used as plant materials. These two varieties were released by the Bangladesh Rice Research Institute (BRRI) in 1994 and suggested to cultivate in *boro* season. The potential yield of BRRI dhan28 and BRRI dhan29 are 6.0 t ha^{-1} and 7.5 t ha^{-1}, respectively (BRRI, 2016).

2.4 Agronomic management

Rice seeds were collected from Agronomy Field Laboratory, Bangladesh Agricultural University. The pregerminated seeds were sown in nursery bed on 9 December 2016 and seedlings were raised with proper care. The experiment was set up in puddled condition on 18 January 2017. Rice varieties were fertilized with 300, 100, 120, 110 and 10 kg ha^{-1} urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate, respectively (BRRI 2016). The entire amount of all fertilizers except urea was applied during the final land preparation. And, urea was applied in three equal installments following top dressing method at 15 days interval after transplanting. Seedlings were transplanted in the experimental plots as per lay out with two seedlings $hill^{-1}$ following 25 cm × 15 cm spacing. The experimental plots were irrigated for six times. BRRI dhan28 and BRRI dhan29 were harvested on 29 April and 18 May 2017, respectively.

2.5 Data collection and analysis

The weed species were collected from the experimental area at 45 DAT and weed density and dry weight were estimated. The dominant weed flora was determined based on the Importance Value (IV) which was calculated by following formula:

$$IV = \frac{n}{N} \times 100 \quad (1)$$

where, IV = Importance Value (%), n and N designate number of an individual species in a community and total number of species in a community.

Weed control efficiency was measured based on weed dry weight and calculated using the formula developed by Sawant and Jadav (1985):

$$WCE = \frac{DWC - DWT}{DWC} \times 100 \quad (2)$$

where, WCE = Weed control efficiency, DWC = Dry weight of weeds in weedy check, and DWT = Dry weight of weeds in each treatment.

Susceptibility of different weed species owing to different weed management practices were graded based on weed control efficiency as suggested by Mian and Gaffer (1968) (Table 2).

Five randomly selected hills (excluding border rows) from each plot were uprooted prior to harvest to record the data of yield contributing attributes. Besides, the harvested crops of central one square meter area from each plot were threshed manually to record yield data. The grains were properly cleaned after sun drying. Finally, the grain weight was adjusted to 14% moisture content (MC) by following formula:

$$\text{MC (\%)} = \frac{W_F - W_O}{W_F} \times 100 \quad (3)$$

$$Y_A = \frac{W_F \times (100 - \%MC)}{100 - 14} \times 100 \quad (4)$$

where, $MC(\%)$ = Moisture content (%), W_F = fresh weight (g), W_O = oven dry weight (g), and Y_A = Adjusted yield at 14% moisure content.

Analysis of variance (ANOVA) was done with the aid of computer package MSTAT-C. Duncan's Multiple Range Test was used to compare the treatment means (Gomez and K, 1984). Cultivation cost was measured from the individual head of expenditure of different agro-inputs.

3 Results

3.1 Weed infestation in rice field

Nineteen weed species belonging to nine families were found in the experimental field. Among 19 weed species, six were grasses, five were sedges and eight were broad leaves. Local, english, scientific and family names of the weeds that found in the experimental plots along their morphological type and life cycle have been shown in Table 3. Results showed that grasses, sedges and broad leaves constituted about 45.38%, 36.41% and 18.21% of total density, respectively at 45 DAT. Perennial and annual weeds constituted 57.89% and 42.11% of the weed population, respectively (data not shown). Based on importance value, the five most dominant weed speciesof the experimental plots were Echinochloa crusgalli (20.55%), Panicum repens (14.40%), Leersia hexandra (9.75%), Fimbristylis miliacea (8.54%) and Scirpus juncoides (8.12%). Whereas, the least dominant weed flora was sedge weed Cyperus difformis (0.57%) followed by sedge weed species Cyperus iria (1.02%) (Table 3).

3.2 Weed density and total dry weight

Weed management practices exerted significant impact on weed density and dry weight at 45 DAT (Table 4). The highest weed density (74.0 m^{-2} in BRRI dhan28 and 65.0 m^{-2} in BRRI dhan29) and dry weight (38.20 g m^{-2} in BRRI dhan28 and 31.25 g m^{-2} in BRRI dhan29) were found in control (no weeding). On the contrary, the lowest weed density (5.67 m^{-2} in BRRI dhan28 and 6.20 m^{-2} in BRRI dhan29) and dry weight (2.76 g m^{-2} in BRRI dhan28 and 2.77 g m^{-2} in BRRI dhan29) were found in Talon 52WP+Clean master 18WP along with hand weeding at 42 DAT (W10) followed by Amchlor 5G + Supermix 18WP along with hand weeding at 35 DAT(W6). For both rice varieties, application of pre-emergence followed by post-emergence herbicide performed better over two hand weeding and single application of herbicides.

3.3 Weed control efficiency

Weed control efficiency (%) of different weed control practices along with grades of weed control and degrees of weed susceptibility are presented in the Table 5. The results showed that pre–followed by post–emergence herbicide along with hand weeding, like Talon 52WP + Clean master18WP along with one hand weeding (W10) provided "excellent control" over weeds. Whereas, Amchlor 5G + Supermix 18WP along with a hand weeding (W6) showed "good control". Treatments like Amchlor 5G + Supermix 18WP (W5), Amchlor 5G + Clean master18WP (W7), Talon 52WP + Clean master18WP (W8), Talon 52WP + Supermix 18WP (W9) and Two hand weeding (W11) produced "fair control". According to weed control efficiency scale as suggested by Mian and Gaffer (1968), moderately susceptible weeds were found in aforementioned pre-emergence followed by post-emergence herbicidal treatments. On the other hand, one additional hand weeding with Talon 52WP + Clean master 18WP performed the best where weeds were very highly susceptible.

Table 1. Description of the herbicides used in the experiment

Common name †	Trade name	Target weed	Dose	Mode of action
Amchlor 5G	Butachlor	Selective for annual grasses, sedges and broadleaves	25 kg ha^{-1}	Pre-emergence
Talon 52WP	Pretilachlor + Triasulfuron	Selective for annual and perennial grasses, sedges and broadleaves	741 g ha^{-1}	Pre-emergence
Supermix 18WP	Benzosulfuran methyl	Selective for shama, panikachu, and other annual sedges	750 g ha^{-1}	Post-emergence
Clean master 18WP	Acetachlor + Bensulfuron	Selective for grasses, sedges and broad leaf and	500 g ha^{-1}	Post-emergence

† Require 4-6 cm standing water in the filed for these herbicides to work.

Table 2. Weed susceptibility grading based on weed control efficiency as suggested by Mian and Gaffer (1968)

Degrees of weed susceptibility	Weed control efficiency	Grades of weed control
Completely susceptible (CS)	100	Completely control (CC)
Very highly susceptible (VHS)	90-99	Excellent control (EC)
Highly susceptible (HS)	70-89	Good control (GC)
Moderately susceptible (MS)	40-69	Fair control (FC)
Poorly susceptible (PS)	20-39	Poor control (PC)
Slightly susceptible (SS)	1-19	Slightly control (SC)
Completely resistant (CR)	0	No control (NC)

Table 3. Infesting weed species found in the experimental plots of boro rice

Sl.	Common name	English name	Scientific name	Family	Type †	IV (%)
1	Shama	Burnyard grass	*Echinochloa crusgalli*	Poaceae	G, A	20.55
2	Khudeshama		*Echinochloa colonum*	Poaceae	G, A	3.05
3	Durba	Bermuda grass	*Cynodon dactylon*	Poaceae	G, P	3.85
4	Angta	Joint grass	*Panicum repens*	Poaceae	G, P	14.4
5	Arail	Swamp rice grass	*Leersia hexandra*	Poaceae	G, P	9.75
6	Angulighash	Crab grass	*Digitaria sangunalis*	Poaceae	G, P	6.04
7	Sobujnakful	Small flower umbrella	*Cyperus difformis*	Cyperaceae	S, P	0.57
8	Joina	Grass like fimbry	*Fimbristylis miliacea*	Cyperaceae	S, P	8.54
9	Bara chucha	Rice flat sedge	*Cyperus iria*	Cyperaceae	S, P	1.02
10	Mutha	Purple nut sedge	*Cyperus rotundus*	Cyperaceae	S, P	1.79
11	Chechra	Bog bulrush	*Scirpus juncoides*	Cyperaceae	S, P	8.12
12	Kochu	Taro	*Calocasia esculenta*	Araceae	B, P	1.58
13	Kanainala		*Cyanotis axillaris*	Commelinaceae	B, A	1.70
14	Monayna	Spreading day flower	*Commelina diffusa*	Commelinaceae	B, A	2.01
15	Kesuti	False daisy	*Eclipta alba*	Compositae	B, A	3.90
16	Panilong	Winged water primrose	*Ludwigia hyssopifolia*	Onagraceae	B, A	2.03
17	Amrulshak	Indian sorrel	*Oxalis corniculata*	Oxalidaceae	B, A	3.43
18	Panikochu	Pickerel weed	*Monochoria vaginalis*	Pontederiaceae	B, P	5.57
19	Biskatali	Smart weed	*Polygonum hydropiper*	Polygonaceae	B, A	2.10

† Morphology (G = grass, S = sedge, B = Broadleaf) and life cycle (A = annual, P = perennial); IV = importance value

Table 4. Influence of weed control practices on weed density and total dry weight in BRRI dhan28 and BRRI dhan29 plots

Treatment	Weed density and dry weight at 45 DAT			
	Density (no. m^{-2})	Dry weight (g m^{-2})	Density (no. m^{-2})	Dry weight (g m^{-2})
	BRRI dhan28		BRRI dhan29	
W0	74.00a	38.20a	65.00a	31.25a
W1	43.00c	26.33b	42.24bc	20.88bc
W2	38.67d	24.22d	41.41c	19.58d
W3	49.00b	24.97c	45.06b	21.50b
W4	37.00d	23.15e	34.96d	19.83cd
W5	25.33ef	14.37g	27.67f	14.02fg
W6	9.33i	4.50j	11.33h	4.267i
W7	23.67fg	13.53h	25.33f	13.29g
W8	20.67gh	11.70i	16.43g	11.17h
W9	27.67e	13.10h	28.67ef	15.40e
W10	5.67j	2.76k	6.20i	2.77j
W11	18.67h	16.47f	31.16e	14.83ef
$S\bar{x}$	1.029	0.2049	1.138	0.4167
Sig. lev.	**	**	**	**
CV (%)	5.74	2.03	6.3	4.59

No weeding (W0), Amchlor 5G as pre-emergence (W1), Talon 52WP as pre-emergence (W2), Supermix 18WP as post-emergence (W3), Clean master 18WP as post-emergence (W4), Amchlor 5G + Supermix 18WP (W5), Amchlor 5G + Supermix 18WP + Hand weeding at 35 DAT (W6), Amchlor 5G + Clean master 18 WP (W7),Talon 52WP + Clean master 18WP (W8), Talon 52WP + Supermix 18WP (W9); Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT (W10), two hand weeding at 21 and at 42 DAT (W11)

Table 5. Weed control efficiency of different weed control practices in BRRI dhan28 and BRRI dhan29 fields

Treatment	BRRI dhan28			BRRI dhan29		
	WCE (%)	Grade	Susceptibility	*WCE* (%)	Grade	Susceptibility
W0	0	NC	CR	0	NC	CR
W1	31.07	PC	PS	33.18	PC	PS
W2	36.60	PC	PS	37.34	PC	PS
W3	34.63	PC	PS	31.20	PC	PS
W4	39.00	PC	PS	36.54	PC	PS
W5	62.38	FC	MS	55.14	FC	MS
W6	88.22	GC	HS	86.34	GC	HS
W7	64.58	FC	MS	57.47	FC	MS
W8	69.00	FC	HS	64.26	FC	MS
W9	65.71	FC	MS	50.72	FC	MS
W10	92.77	EC	VHS	91.14	EC	VHS
W11	56.88	FC	MS	52.54	FC	MS

WCE = weed control efficeincy (%), Grade = grade of weed control, and Susceptibility = degree of weed susceptibility; No weeding (W0), Amchlor 5G as pre-emergence (W1), Talon 52WP as pre-emergence (W2), Supermix 18WP as post-emergence (W3), Clean master 18WP as post-emergence (W4), Amchlor 5G + Supermix 18WP (W5), Amchlor 5G + Supermix 18WP + Hand weeding at 35 DAT (W6), Amchlor 5G + Clean master 18WP (W7),Talon 52WP + Clean master 18WP (W8), Talon 52WP + Supermix 18WP (W9); Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT (W10), two hand weeding at 21 and at 42 DAT (W11); CC= Complete control (100%), EC= Excellent control (90-99%), GC= Good control (70-89%), FC= Fair control (40-69%), PC= Poor control (20-39%), SC= Slightly control (1-19%), NC= No control (0%) CS = Completely susceptible (100%), VHS = Very highly susceptible (90-99%), HS = Highly susceptible (70-89%), MS = Moderately susceptible (40-69%), PS = Poorly susceptible (20-39%), SS = Slightly susceptible (1-19%), CR = Completely resistant (0%)

3.4 Yield contributing characters of rice

Significant influence of weed control practices was observed on the yield contributing characters and yield of BRRI dhan28 and BRRI dhan29 and shown in Table 6 and Table 7, respectively. In case of BRRI dhan28, the highest number of total tillers hill^{-1} (17.67), effective tillers hill^{-1} (15.33), number of grains panicle^{-1} (93), 1000 grain weight (23.62 g), grain yield (5.5 t ha^{-1}), straw yield (5.87 t ha^{-1}) and biological yield (11.37 t ha^{-1}) were recorded in Talon 52WP + Clean master 18WP along with hand weeding at 42 DAT (W10) followed by Amchlor 5G + Supermix 18WP along with hand weeding at 35 DAT (W6) (Table 6).

In BRRI dhan29, number of total tillers hill^{-1} (19.10), effective tillers hill^{-1} (15.33), number of grains panicle^{-1} (96.75), 1000-grain weight (24.1 g), grain yield (6.23 t ha^{-1}), straw yield (6.73 t ha^{-1}) and biological yield (12.96 t ha^{-1}) were found maximum in Talon 52WP + Clean master 18WP along with hand weeding at 42 DAT (W10) followed by Amchlor 5G +Super mix 18WP along with hand weeding at 35 DAT (W6) (Table 7). Irrespective of rice varieties, treatments like pre-emergence herbicide followed by post-emergence herbicide and two hand weeding produced statistically similar number of effective tillers hill^{-1} and 1000-grain weight. But, pre-emergence herbicide followed by post-emergence herbicide was statistically superior to two hand weeding in terms of producing number of grains panicle^{-1}, grain yield and straw yield. The lowest value of yield contributing parameters and yield was observed in unweeded condition.

3.5 Economics of the weeding regimes

The budget analysis of different weed management practices is provided in the Table 8. Partial budget analysis revealed that, the highest net income (58050 Tk ha^{-1} in BRRI dhan28 and 61229 Tk ha^{-1} in BRRI dhan29) and B:C ratio (1.81 in BRRI dhan28 and 1.86 in BRRI dhan29) were recorded in Talon 52WP + Clean master 18WP along with hand weeding at 42 DAT(W10). Whereas, Amchlor 5G + Supermix 18WP along with hand weeding at 35 DAT (W6) produced the second highest net return (56480 Tk ha^{-1} in BRRI dhan28 and 58806 Tk ha^{-1} in BRRI dhan29) as well as B:C ratio (1.78 in BRRI dhan28 and 1.82 in BRRI dhan29). Besides, higher net profit was also obtained from pre-emergence herbicide followed by post-emergence herbicide than two hand weeding (W11). The lowest profit was achieved from the control (W0) treatment.

4 Discussion

The present study showed that *Echinochloa crusgalli*, *Panicum repens*, *Leersia hexandra*, *Fimbristylis miliacea*, and *Scirpus juncoides* appeared as the most dominant weed species in the study area. *Echinochloa crusgalli* dominated weed species in rice were also reported by others (Afroz et al., 2019; Islam et al., 2018; Popy et al., 2017) at the same location. Weed competes with crop aggressively due to their high growth rate, high potential to acclimatize changing environment and more efficient seed production (Swanton et al., 2015). Most of the studies showed that crop-weed competition at early growth stage (from 15 to 45 DAS) had significant effect on yield of wet seeded rice (Moody, 1993; Ladu and Singh, 2006; Sangeetha et al., 2009). Generally, farmers practice 2-3 hand weeding to control weeds. But scarcity of labor during the peak period has currently become a serious problem led to delaying in weeding, which results in drastic yield reduction because of high crop-weed competition (Hasanuzzaman et al., 2009; Rashid et al., 2012). To prevail over this problem, researchers stand in using herbicides as potential weed control practice to reduce labor inputs (Ahmed et al., 2001). The weed seedbank in the soil acts as the prime source of weed infestations (Cavers, 1983). This phenomenon favors continuous emergence of weed throughout crop growing season and speed-up crop-weed competition. Mahajan and Chauhan (2015) reported that the time frame of pre-emergence herbicide application is very short and often, farmers fail to take the advantage of optimum time application. Hence, successive application of pre-emergence and post-emergence herbicides suppressed the early and late flushes of weeds more efficiently compared to sole application of herbicide (Mahajan and Chauhan, 2013). And, one additional hand weeding helps in the reduction of weed pressure throughout the critical period resulting the highest weed control efficiency (Dhakal et al., 2019).

In this experiment, Talon 52WP followed by post-emergence herbicide; Clean master 18WP along with hand weeding at 42 DAT revealed excellent weed control efficiency over Amchlor 5G followed by Supermix 18WP along with hand weeding at 35 DAT. This is might be due to broad spectrum effect of Talon 18WP and Clean master 18WP on both annual and perennial grass, sedge and broadleaf at early stage of crop growth. This result is corroborated with that reported by other researchers (Lin, 2000; Banerjee et al., 2008; Saha and Rao, 2009; Ahmed and Chauhan, 2014). On the other hand, Amchlor 5G and Supermix 18WP are mostly selective to annual grasses, sedges and few broadleaves. The study also revealed that treatments like Amchlor 5G + Supermix 18WP, Amchlor 5G + Clean master 18WP, Talon 52WP + Clean master 18WP and Talon 52WP + Super mix 18WP showed higher weed control efficiency over two hand weeding treatment. While others reported the minimum weed pressure and the maximum weed control efficiency under two hand weeding treatment (Kumar et al., 2017; Rekha et al., 2002; Singh and Deo, 2004).

Table 6. Influence of weed control practices on yield contributing characters and yield of BRRI dhan28

Treatment	Total tillers hill^{-1}	Eff. tillers hill^{-1}	Non-eff. hill^{-1}	Panicle length (cm)	Grains pan^{-1} (no)
W0	12.67e	10.33 e	2.33abc	17.73c	72.67f
W1	13.67 de	11.67 de	2.00bc	20.37 b	80.00e
W2	14.00de	10.67e	3.33ab	21.49ab	80.00e
W3	15.00cd	11.00de	4.00a	21.51ab	81.67de
W4	14.67cd	11.33de	3.33abc	21.48ab	82.33d
W5	16.00bc	13.67bc	2.33abc	22.55a	85.00c
W6	16.67ab	14.33ab	2.33abc	21.84ab	87.67b
W7	15.67bc	13.33bc	2.33abc	22.85a	85.33c
W8	16.33bc	13.33bc	3.00abc	22.11ab	87.00b
W9	16.33bc	13.00bc	3.33ab	22.88a	85.67c
W10	17.67a	15.33a	2.33abc	22.59a	93.00a
W11	15.67bc	13.33 bc	2.33abc	22.78a	81.00de
$S\bar{x}$	0.512	0.643	0.509	0.579	0.649
Sig. lev.	**	**	**	*	**
CV (%)	5.77	8.75	7.38	4.63	4.35
Treatment	WTS (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	BY (t ha^{-1})	HI (%)
W0	20.81c	3.17j	4.22h	7.40j	42.82e
W1	21.13c	3.55h	3.97i	7.52j	47.24c
W2	21.42c	3.76f	4.47g	8.23h	45.70d
W3	21.73bc	3.32i	4.56g	7.87i	42.13e
W4	21.92bc	3.66g	5.02e	8.67g	42.16e
W5	22.00bc	4.70d	5.12e	9.82e	47.84bc
W6	22.23abc	5.26b	5.62b	10.88b	48.36ab
W7	22.12abc	4.78d	5.32d	10.10d	47.31c
W8	22.24abc	5.20bc	5.45c	10.66c	48.86a
W9	22.20abc	5.15c	5.37cd	10.52c	48.95a
W10	23.62a	5.50a	5.87a	11.37a	48.38ab
W11	23.04ab	3.983e	4.85f	8.83f	45.11d
$S\bar{x}$	0.464	0.0316	0.107	0.048	0.258
Sig. lev.	*	**	**	**	*
CV (%)	3.64	3.2	2.27	3.9	3.96

In column, figures with similar letter (s) do not differ significantly while figures with dissimilar letter differ significantly (according to DMRT), ** = Significant at 1% level of probability, * =Significant at 5% level of probability, CV = Co-efficient of variance; No weeding (W0), Amchlor 5G as pre-emergence (W1), Talon 52WP as pre-emergence (W2), Supermix 18WP as post-emergence (W3), Clean master 18 WP as post-emergence (W4), Amchlor 5G + Supermix 18WP (W5), Amchlor 5G + Supermix 18WP + Hand weeding at 35 DAT (W6), Amchlor 5G + Clean master 18WP (W7), Talon 52WP + Clean master 18WP (W8), Talon 52WP + Supermix 18WP (W9); Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT (W10), two hand weeding at 21 and at 42 DAT (W11)

Table 7. Influence of weed control practices on yield contributing characters and yield of BRRI dhan29

Treatment	Total tillers hill^{-1}	Eff. tillers hill^{-1}	Non-eff. hill^{-1}	Panicle length (cm)	Grains pan^{-1} (no)
W0	13.47g	11.10g	2.370b	19.97ab	80.65g
W1	14.13g	12.49f	2.647b	20.61b	84.24f
W2	15.90f	12.47f	3.43a	22.19ab	85.11ef
W3	15.80f	12.64f	3.46a	23.15a	86.32ef
W4	15.83f	13.00ef	3.29a	20.66b	87.65de
W5	16.53cde	13.10cde	3.43a	22.03ab	89.73cd
W6	17.17b	13.87b	3.29a	21.89ab	92.38bc
W7	16.74cde	13.39cde	3.35a	21.55ab	90.56cd
W8	17.03cd	13.74cd	3.30a	21.88ab	91.76c
W9	16.85cde	13.40cde	3.45a	20.58b	91.37c
W10	19.10a	15.53a	3.56a	21.20b	96.75a
W11	16.14cd	13.77cd	3.37a	21.95ab	90.02cd
S$\bar{x}$	0.245	0.253	0.097	0.537	1.07
Sig. lev.	**	**	**	*	**
CV (%)	3.64	4.68	7.38	6.09	2.92
Treatment	**WTS (g)**	**Grain yield (t ha^{-1})**	**Straw yield (t ha^{-1})**	**BY (t ha^{-1})**	**HI (%)**
W0	20.12bc	3.27h	4.31h	7.58i	43.14d
W1	21.12bc	4.45g	5.04g	9.497h	46.82bc
W2	21.37bc	4.74f	5.40f	10.14gh	46.64c
W3	21.68bc	5.08e	5.43f	10.52fg	48.47a
W4	21.76bc	5.06e	5.73e	10.79f	48.42a
W5	22.19ab	5.45d	5.85e	11.31de	48.27ab
W6	22.23ab	5.92b	6.37bc	12.30abc	48.18ab
W7	22.22ab	5.54d	5.99de	11.54cde	47.96bc
W8	22.20ab	5.84c	6.17cd	12.02bcd	48.63a
W9	22.21ab	5.79c	6.02de	11.81bcd	49.01a
W10	24.14a	6.23a	6.73a	12.96a	48.11bc
W11	22.18ab	4.25gh	4.54ab	8.79 gh	48.02bc
S$\bar{x}$	0.64	0.068	0.102	0.275	0.474
Sig. lev.	*	**	**	**	*
CV (%)	7.14	3.12	4.32	6.01	2.42

In column, figures with similar letter (s) do not differ significantly while figures with dissimilar letter differ significantly (according to DMRT), ** = Significant at 1% level of probability, * =Significant at 5% level of probability, CV = Co-efficient of variance; No weeding (W0), Amchlor 5G as pre-emergence (W1), Talon 52WP as pre-emergence (W2), Supermix 18 WP as post-emergence (W3), Clean master 18 WP as post-emergence (W4), Amchlor 5G + Supermix 18WP (W5), Amchlor 5G + Supermix 18WP + Hand weeding at 35 DAT (W6), Amchlor 5G + Clean master 18 WP (W7),Talon 52WP + Clean master 18WP (W8), Talon 52WP + Supermix 18WP (W9); Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT (W10), two hand weeding at 21 and at 42 DAT (W11)

Table 8. Partial budget-analysis of different weed control practices (BDT ha^{-1}) in boro rice

Treatment	Vc	Hc	Lc	TC	BRRI dhan28			BRRI dhan29		
					GI	NR	BCR	GI	NR	BCR
W0	55950	0	0	55950	64125	8175	1.15	65253	9303	1.17
W1	55950	1125	520	57595	73835	16240	1.28	74853	17258	1.3
W2	55950	629	520	57099	75866	18767	1.33	77030	19931	1.35
W3	55950	675	520	57145	72666	15521	1.27	74440	17295	1.3
W4	55950	400	520	56870	73650	16780	1.3	75257	18387	1.32
W5	55950	1800	1040	58790	99680	40890	1.7	101117	42327	1.72
W6	55950	16100	14300	72050	127530	56480	1.78	130856	58806	1.82
W7	55950	1525	1040	58515	104255	44740	1.76	104533	46018	1.79
W8	55950	1029	1040	58019	99309	41290	1.71	101141	43122	1.74
W9	55950	1374	1040	58364	101954	43590	1.75	104239	45875	1.79
W10	55950	15329	14300	71250	129300	58050	1.81	132479	61229	1.86
W11	55950	0	28600	84550	127100	42550	1.57	129904	45354	1.54

Vc = variable cost, Hc = herbicide cost, Lc = labour cost, TC = total cost, GI = gross income, NR = net return, BCR = benefit-cost ratio; One man-day labourer was valued at 260 Tk ;
Amchlor 5G = 1125 Tk @ 45 Tk kg^{-1}, Talon 52WP = 629 Tk @ 85 Tk 100 g^{-1}, Supermix 18WP = 675 Tk @ 90 Tk 100 g^{-1}, Clean master 18WP = 400 Tk @ 80 Tk 100g^{-1}; No weeding (W0), Amchlor 5G as pre-emergence (W1), Talon 52WP as pre-emergence (W2), Supermix 18WP as post-emergence (W3), Clean master 18WP as post-emergence (W4), Amchlor 5G + Supermix 18WP (W5), Amchlor 5G + Supermix 18WP + Hand weeding at 35 DAT (W6), Amchlor 5G + Clean master 18WP (W7), Talon 52WP + Clean master 18WP (W8), Talon 52WP + Supermix 18WP (W9); Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT (W10), two hand weeding at 21 and at 42 DAT (W11)

The probable cause of the present finding was mimic nature of weed, which help them to escape at the early crop growth stage and compete with crop. Rao and Moody (1988) reported that identical growth of grasses like *Echinochloa crusgalli* and rice seedlings increases the difficulty of manual weeding. On the contrary, the highest weed pressure was observed in unweeded plots owing to unchecked growth of weeds, which provide unlimited competition to crop.

The highest grain yield, biological yield were recorded in Talon 52WP + Clean master 18WP along with hand weeding at 42 DAT followed by Amchlor 5G + Supermix 18WP along with hand weeding at 35DAT. The possible reason of higher yield of rice was the effect of herbicides on weeds so rice plants received more water, air, light, space and nutrients for their optimum growth and development and this favored in developing higher number of yield contributing attributes. Moreover, the growing number of foliage might have promoted the photosynthesis owing to low crop-weed competition, which acts as source of higher yield under this treatment. Dhakal et al. (2019) also reported the similar result. Besides, economic study of different weed management practices revealed that the highest profit was obtained from Talon 52WP + Clean master 18WP along with hand weeding at 42 DAT. Moreover, Amchlor 5G + Supermix 18WP along with hand weeding at 35 DAT also produced higher profit over two hand weeding. This is due to less labor cost involvement compared to two hand weeding. Sathyamoorthy et al. (2004) and Parvez et al. (2013) also reported that herbicides (pre-emergence and post-emergence) with hand weeding would help to achieve the maximum crop yield with less efforts and cost. On the other hand, treatments like pre-emergence herbicide followed by post emergence herbicide (Amchlor 5G + Supermix 18WP, Amchlor 5G + Clean master 18WP, Talon 52WP + Clean master 18WP, and Talon 52WP + Supermix 18WP) seemed to be more valuable than two hand weeding owing to its ability to control only a portion of the weed population at the earlier growth stage and minimum labor charge involvement.

5 Conclusions

The present study showed that Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT, Amchlor 5G + Supermix 18WP along with hand weeding at 35 DAT, Amchlor 5G + Supermix 18WP, Amchlor 5G + Clean master 18WP, Talon 52WP + Clean master 18WP and Talon 52WP + Supermix 18WP were more remunerative than two hand weeding. Considering available resources such as labor, farmers' can proceed with any one of the aforementioned herbicidal weed management practices. But based on the present findings Talon 52WP + Clean master 18WP + Hand weeding at 42 DAT appeared as the most promising practice regarding weed control and yield with the highest net profit and B:C ratio for BRRI dhan28 and BRRI dhan29. However, as herbicide application has been expanding quickly in Bangladesh, effects of repeated use of herbicide for a long time on soil health has become a burning issue and demand attention for subsequent investigation before arriving at any exact decision.

Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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The Official Journal of the **Farm to Fork Foundation**
ISSN: 2518–2021 (print)
ISSN: 2415–4474 (electronic)
http://www.f2ffoundation.org/faa